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Proceedings of a Workshop on Canadian Science and Management Strategies for Sea Cucumber (*Cucumaria frondosa*)

Compte rendu d'un atelier sur les stratégies canadiennes en matière d'étude scientifique et de gestion de l'holothurie (*Cucumaria frondosa)*

17–18 June 2008

Les 17 et 18 juin 2008

Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Institut océanographique de Bedford
Dartmouth (Nouvelle-Écosse)

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August 2009

Août 2009

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

This workshop was not carried out as a formal Fisheries and Oceans Canada (DFO) Science Advisory process; however, it is being documented in the Canadian Science Advisory Secretariat's (CSAS) Proceedings series as it presents some topics of interest related to the advisory process.

Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenus dans le présent rapport puissent être inexacts ou propres à induire en erreur, ils sont quand même reproduits aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considéré en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

Le présent atelier n'a pas été tenu dans le cadre officiel du processus des avis scientifiques du ministère des Pêches et des Océans (MPO). Celui-ci est toutefois documenté dans la série des comptes rendus du Secrétariat canadien de consultation scientifique (SCCS), car il couvre certains sujets en lien avec le processus des avis.

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SUMMARY

Interest in harvesting sea cucumber (*Cucumaria frondosa*) in the Maritimes began in 1989, but the fishery was slow to develop mainly due to lack of market potential, as this species is thin-walled relative to other sea cucumber species fished internationally. One experimental fishing licence was issued in 1996, although the small catches of small thin-walled animals were not marketable. In 1999, there was renewed interest in harvesting sea cucumber, and 6 experimental/exploratory licences exist in the Scotia-Fundy area at present. Experimental sea cucumber fishing activities have also been ongoing in the Gulf of Maine since 1988 and off Newfoundland since the 1990s. While the sea cucumber fishery is an emerging fishery in Atlantic Canada, Fisheries and Oceans Canada (DFO) has recognized that a requirement exists to develop a comprehensive fisheries management plan governing activities of current and future licence holders. Although there is little biological information available from the Maritimes, other regions (e.g., Newfoundland) and countries (e.g., USA) have undertaken scientific studies on this and related species (e.g., Pacific sea cucumber (*Parastichopus californicus*)). In this regard, there is a need to develop an understanding of the information that exists to assist management, the approaches that could be used for management, and future information needs. These proceedings document discussions held during 17–18 June 2008 on these issues.

SOMMAIRE

Bien que l'intérêt à l'égard de la récolte de l'holothurie (Cucumaria frondosa) dans les Maritimes remonte à 1989, cette pêche a connu une lente évolution, essentiellement en raison de son faible potentiel commercial, cette espèce étant une parente à parois minces des autres espèces d'holothuries pêchées dans le monde. Un permis de pêche expérimentale a été délivré en 1996, mais les faibles quantités de petites holothuries à parois minces qu'on a capturées n'étaient pas commercialisables. En 1999, la pêche de l'holothurie a suscité un regain d'intérêt, et six permis de pêche expérimentale ou exploratoire sont présentement en vigueur dans la région Scotia-Fundy. Des activités de pêche expérimentale de l'holothurie se déroulent aussi dans le golfe du Maine depuis 1988, et au large de Terre-Neuve depuis les années 1990. Même si la pêche de l'holothurie doit être qualifiée de pêche émergente au Canada atlantique, Pêches et Océans Canada (MPO) a reconnu le besoin de formuler un plan de pêche exhaustif pour réglementer les activités des détenteurs de permis actuels et futurs. S'il existe encore peu de renseignements sur la biologie de cette espèce dans les Maritimes, d'autres régions (p. ex. Terre-Neuve) et pays (p. ex. les États-Unis) ont mené des études scientifiques sur l'holothurie et des espèces voisines, dont le concombre de mer du Pacifique (Parastichopus californicus). À cet égard, il y a lieu de mieux comprendre l'information existante pour aider la gestion de cette pêche, les stratégies à utiliser pour cette gestion et les futurs besoins de renseignements. Le présent rapport décrit les échanges tenus les 17 et 18 juin 2008 sur ces questions.

INTRODUCTION

Interest in harvesting sea cucumber (*Cucumaria frondosa*) in the Maritimes began in 1989, but the fishery was slow to develop mainly due to lack of market potential as this species is thin-walled relative to other sea cucumber species fished internationally. One experimental fishing licence was issued in 1996, although the small catches of small thin-walled animals were not marketable. In 1999, there was renewed interest in harvesting sea cucumber, and 6 experimental/exploratory licences exist in the Scotia-Fundy area at present. Experimental sea cucumber fishing activities have also been ongoing in the Gulf of Maine since 1988, and off Newfoundland since the 1990s.

While the sea cucumber fishery is an emerging fishery in Atlantic Canada, Fisheries and Oceans Canada (DFO) has recognized that a requirement exists to develop a comprehensive fisheries management plan governing activities of current and future licence holders. Although there is little biological information available from the Maritimes, other regions (e.g., Newfoundland) and countries (e.g., USA) have undertaken scientific studies on this and related species (e.g., Pacific sea cucumber (*Parastichopus californicus*)). In this regard, there is a need to develop an understanding of the information that exists to assist management, the approaches that could be used for management, and future information needs.

A workshop was therefore convened in the Auditorium at the Bedford Institute of Oceanography (BIO) during 17 – 18 June 2008, to address the Terms of Reference (Appendix 1), which had been developed jointly by DFO Fisheries and Aquaculture Management and Science branches. The Chair, Ross Claytor, opened the meeting by welcoming the participants (Appendix 2), which included experts from other parts of Canada and the USA. The Chair then reviewed the Terms of Reference, which included the workshop's context and objectives. He noted that the main product of the workshop was to be these proceedings. The Agenda (Appendix 3) was then reviewed. The Chair noted that the first day was to be primarily devoted to presentations and discussion on sea cucumber biology and fisheries, while the second day would be devoted to the science needs of potential management approaches and priorities. He also noted that the agenda was deliberately designed to allow lots of time for discussion.

PRESENTATIONS

Science before the Fishery – Growth Rates, Predation, and Gene Flow of the Sea Cucumber, *Cucumaria frondosa*

Justin So, Sven Uthicke, Jean-Francois Hamel, and Annie Mercier

Presentation Highlights

As world sea cucumber fisheries decline, alternative species such as *Cucumaria frondosa* are being considered for future fisheries. In this study, growth rates, predation pressure, and gene flow between distant populations were investigated. Eight size classes of sea cucumbers were kept in tanks provided with running unfiltered seawater under natural conditions of photoperiod for a minimum of 16 months. The smallest size class was comprised of recruits obtained from spawning in the laboratory and monitored for 24 months. All size classes exhibited seasonal growth with increases in immersed weight after spring peaks of phytoplankton abundance. Overall, growth rates were very low and negative trends were observed in some classes. The main predator of *C. frondosa*, the asteroid *Solaster endeca*, occurred sympatrically in almost all sites surveyed. The maximum density of *S. endeca* was 0.05 individuals/m^2 and its average abundance was approximately 0.01 individuals/m^2. Under controlled laboratory conditions,

S. endeca was found to consume 2-4 sea cucumbers per month. Its feeding rate was modulated by seawater temperature. Moreover, *S. endeca* preyed more intensely upon small sea cucumbers (approximately 7 cm in length) than large ones (approximately 14 cm). Based on these findings, *S. endeca* can potentially remove an average of 0.28 sea cucumbers/m^2 annually. Feeding trials also demonstrated that sea cucumbers damaged by trawling activities can attract seastars suggesting that predatory pressure could increase over time. *C. frondosa* has high dispersal lecithotrophic larvae that can stay in the water column for up to 46 days, potentially providing recruitment to distant populations. Mitochondrial DNA (mtDNA) was extracted and sequenced from a total of 345 sea cucumbers collected from 20 locations (separated up to 5000 km) throughout the north Atlantic. Hierarchical Analyses of Molecular Variance (AMOVA) indicated no significant population separation either between 6 major geographic regions (Φ_{SC}=0.0081, p=0.127) or for populations within regions (Φ_{CT}=0.0045, p=0.0045), and most variation (98.78%) occurred within populations. In addition, neither the Φ_{ST} values nor corrected genetic distance (Kimura 2 Parameters) showed any signs for isolation by distance. In contrast, exact test for population differentiation were overall significant ($p<0.05$) and showed significant differentiation of several pairs of populations, irrespective of their geographic distance. This indicates that this species shows strong genetic patchiness as was recently described for several other marine species. Sporadic recruitment or low genetic variability in surviving larval recruits was previously suggested to explain that pattern. Thus, most of the north Atlantic *C. frondosa* collected appear to be part of a large population connected through high gene flow facilitated by long larval life. Local genetic patchiness can occur, however, with variations in sources of recruitment over ecological time scales. An international management plan for this wide ranging population is needed to ensure a sustainable fishery for all countries. If genetic patchiness is confirmed, additional 'local' management would be required through closure of apparently less connected areas. In addition, slow growth rates and high predatory pressure enhanced by fishing activities emphasizes the need for a precautionary approach to managing this emerging fishery.

Discussion

Following the presentation, a question was posed regarding the degree to which the laboratory environment may have contributed to the slow growth rates observed. J. So indicated that sea cucumbers typically respond well to captivity, engaging in normal feeding and spawning behaviour; and studies in the Gulf of St. Lawrence have suggested similar growth rates between field and laboratory environments. So also noted that growth and maximum size appeared to be considerably lower in Newfoundland relative to the Gulf of St. Lawrence, which may reflect differences in food abundance between the two areas.

A participant noted that body wall thickness can vary dramatically among individuals and asked whether this variable might be related to age. A. Mercier indicated that *C. frondosa* has the ability to accumulate energy reserves in the body wall and, as a result, there is often considerable variation in body wall thickness among individuals and across seasons. Another participant noted that sea cucumbers in an area are often similar in size and asked whether juveniles and adults might live in different habitats. So replied that juveniles may be found in shallower water than the adults, sometimes even in the intertidal zone, living under boulders. R. Singh added that he has observed juveniles among corraline algae. Mercier indicated that small sea cucumbers are cryptic, perhaps migrating from shallow inshore areas to deeper areas over time. S. Grant noted that intermediate sized sea cucumbers are sometimes found in discrete patches on St. Pierre Bank, but harvesters do not return to these areas because the animals are smaller than the target size for harvest.

The Chair asked what might be considered the average life span for *C. frondosa* and Mercier indicated that this is unknown. The Chair proceeded to inquire about size at maturity and Mercier indicated that on St. Pierre Bank, maturity occurs at approximately 10 cm, while market sized animals are typically less than 15-20 cm in length. When asked whether individual *C. frondosa* spawn annually, Mercier replied that this is unknown, although spawning appears to be linked to environmental conditions. On the subject of population structuring, one participant questioned whether similar conclusions would have been reached if different methodology had been applied – in particular, it was noted that restrictions in gene flow and genetic differences in life history traits, such as growth rate, may exist at spatial scales that can not be fully resolved by examining mitochondrial DNA. In this regard, it was suggested that use of microsatellite DNA or a common-garden experimental protocol could reveal population structuring at much smaller spatial scales than the present study.

Global Overview of Sea Cucumber Fisheries and Resource Assessment with a Focus on the Specificities of *Cucumaria frondosa*
Annie Mercier and Jean-Francois Hamel

Presentation Highlights

Worldwide sea cucumber fisheries date back several centuries and currently target over 80 edible species. Commercial sea cucumber harvests in the temperate northern hemisphere are much more limited and recent, centering on 4 species (*Parastichopus californicus, P. parvimensis, Cucumaria frondosa*, and *C. japonica*) with fisheries data available from Canada, the USA, Russia, and Iceland (Hamel and Mercier 2008a). In North America, *Parastichopus* fisheries emerged in the early 1970s, and most fisheries of *Cucumaria* are still in the early exploratory phase, especially in Canada. The *Parastichopus* species are typically hand picked by divers and thus exploited at a scale that is similar to what occurs in the tropical Indo-Pacific regions. However, the exploitation of the *Cucumaria* species generally involves industrialized processes (i.e., fishing boats, specialized trawls, and processing plants). Differences in biological features, stock abundances, catch efforts, and socio-economic importance of the resource are easily identifiable and should be carefully evaluated in light of worldwide experience to develop proper management strategies for *C. frondosa* in eastern Canada (Hamel and Mercier 2008b).

Discussion

A participant asked what might be the average density of *C. frondosa* in the wild and Mercier indicated that 5-10 sea cucumbers/m^2 would not be unusual and that some seemingly suitable habitats contain no sea cucumber. Mercier noted that *C. frondosa* often occurs on vertical surfaces which might help populations persist when faced with fishing pressure as it is difficult to drag there. High densities are believed to be critical for reproductive success in this broadcast spawner. Mercier noted that she observed a natural spawning event of *C. frondosa* in the Gulf of St. Lawrence and reported fertilization rates up to 95% in the surface layer (Hamel and Mercier 1996).

Lessons Learned from Global Sea Cucumber Fisheries
Susanna Fuller

Presentation Highlights

Globally, trends in sea cucumber fisheries follow a bell shaped curve, with an initial increase in catch following the start of a fishery in a new area, a peak in catch, and then a decline from

which stocks do not readily recover. When considering these trends, it is important to note that all sea cucumber fisheries, with the exception of that for *Cucumaria frondosa*, are dive fisheries. As the primary market for sea cucumbers is Japan, cucumber populations are being exploited farther and farther away from the market as populations decline and new species are sought. Given that the *Cucumaria* fishery in the northwest Atlantic and, in particular, Canadian waters is a drag fishery, additional precaution needs to be taken beyond simple stock assessment as drags cause habitat damage and indirect mortality on target and non-target species. In order to prevent against following the trend in fisheries collapses that characterized the majority of sea cucumber fisheries, it is recommended that the sea cucumber fishery in Atlantic Canada be managed through a precautionary ecosystem approach. Management decisions should be based on a spatial model that provides protection for sea cucumber habitat, particularly given that reproduction requires chemical cues and large aggregations of sea cucumbers. It is also recommended that where ever possible, particularly on the inshore, sea cucumbers be taken through a dive fishery.

Discussion

During the presentation, S. Fuller indicated that there are many unknown aspects of sea cucumber life history. And, afterwards, there was a question regarding the degree to which this comment was accurate, particularly given recent work undertaken in Newfoundland. Fuller clarified by indicating that she was referring to the Scotia-Fundy area. Mercier stated that there is much information available for *C. frondosa*, particularly in the Gulf of St. Lawrence, although given that there is likely spatial variation in life history characteristics and that the Gulf of St. Lawrence may reflect an area with particularly high growth rates, additional studies should be conducted in other locations such as Scotia-Fundy.

One participant questioned whether there are examples of spatially-based management for other sea cucumber fisheries. Duprey indicated that a rotational fishery for *P. californicus* was attempted in British Columbia during the early 1990s but it was stopped, and is presently in the process of being re-initiated. Mercier noted that Alaska also has a rotational fishery.

Pacific Sea Cucumber (*Parastichopus californicus*) Fishery
Nicholas Duprey

Presentation Highlights

The giant red sea cucumber (*Parastichopus californicus*) has been harvested commercially via SCUBA or hooka in British Columbia since 1971. Due to a rapid increase in harvesting, beginning in the mid to late 1980s, several management techniques were attempted to curb the fishery's expansion. Arbitrary quotas were introduced in 1986 and were subsequently reduced 3 times, resulting in a quota reduction of 56% between 1989 and 1994. In 1997, the fishery was labeled a 'developing and data-limited fishery' resulting in the introduction of a phased management approach. Phase 0 consisted in reviews of existing knowledge of the fishery and biology of *P. californicus*. Other giant red sea cucumber fisheries in the Pacific, including the state fisheries of Washington and Alaska, were studied to develop a precautionary baseline density for the British Columbia coast and to set precautionary exploitation rates. These precautionary exploitation rates and density estimates were used to calculate population biomass and quotas for each Pacific Fishery Management Subarea open to harvesting. This led to recommendations to proceed to Phase 1 of the fishery involving restricted fishing, while collecting more data to assess fishery impacts and appropriate harvesting levels for the British Columbia population. During Phase 1, a static 25% of the coast was open for annual harvesting, while 25% was reserved for experimental use and the remaining 50% was closed. SCUBA

surveys were conducted in 6 locations through British Columbia where commercial harvesting was taking place. The surveys were conducted in 4-year rotations to provide local density and biomass data. Local density data were collected to update density data for sea cucumbers in regions throughout British Columbia. Gradual increases in quota occurred between 1997 and 2006 as baseline densities were shown to be higher than precautionary estimates drawn from Alaska. Harvest logbooks provided much georeferenced data on harvester behaviour and effort. These data were spatially analyzed to better understand the movement, effort exertion, and impacted areas along the coast of British Columbia. Four experimental fishery areas (EFA) were developed to conduct experiments into appropriate exploitation rates for a British Columbia fishery. In each EFA, 5 equal sized sites were selected, each one receiving 1 of 5 exploitation rates: 0%, 2%, 4%, 8%, and 16%. Each site was SCUBA surveyed to calculate densities and population biomass allowing modeling of the impact of harvest rate on the population.

Discussion

Following the presentation, there was a question regarding whether licence holders are tied to a particular location or whether it is a competitive fishery. N. Duprey indicated that licences are tied to one of three areas and weighted according to the quota for that particular area.

One participant inquired whether there would be a no-take area within each Pacific Fishery Management Area and, if so, how would they decide on size? Duprey indicated that there would likely be a no-take area within each Pacific Fishery Management Area, although size was yet to be determined. Mercier asked whether biological studies were being undertaken to guide establishment of reserves (e.g., location of spawning areas). Duprey replied that he was not aware of any studies detailing spatial differences in biology, and that they would try to select representative areas as opposed to those that contained particularly high or low concentrations of sea cucumber.

When asked whether there was any form of size selection in the fishery, Duprey indicated that there is no minimum size at present – harvesters are assumed to remove sea cucumber irrespective of size, although they may preferentially take large individuals in areas of particularly high density. Another question was posed regarding whether sea cucumbers are distributed beyond 20 m depth (the outer bounds of the survey areas). Duprey indicated that although sea cucumbers can be found in depths up to approximately 250 m, they are mostly harvested by divers within the survey areas. That being said, there may be migration of animals between deep water areas and the fishing grounds.

An Assessment of Sea Cucumber Stock in Maine
Yong Chen, Scott Feindel, Glenn Nutting, Sheril Kirshenbaum, and Linda Mercer

Presentation Highlights

The sea cucumber is a relatively new but rapidly expanding fishery in Maine. Like other new fisheries rapidly developed as a result of newly found markets, we have little knowledge about the status of the Maine sea cucumber resources and impacts of the fishery on the resources. We conducted this cooperative research to: 1) survey the sea cucumber resources in major sea cucumber fishing grounds along the coast of Maine; and 2) collect biological information of the Maine sea cucumber population.

Through cooperative research, both fishers and scientists participated in a large-scale survey of the population from 2005 to 2007 in Frenchman and Narraguagus bays, which yielded more than 90% of sea cucumber landings in Maine. The survey suggested that rock bottom was the

most favorable habitat for sea cucumber in the survey area and that exploitable stock biomass varied with depth, with sea cucumber more abundant in shallow waters (less than 20 m). Stock biomass decreased substantially from 2005 to 2006, but was stable from 2006 to 2007. This study suggested that the major spawning event of sea cucumber occurs from January to March, but minor spawning events may also occur in other months. Differences in water temperature among different depths and seasons may account for differences in gonad development at different depths.

The findings of this project have significant long-term impacts on the management of the sea cucumber fishery in Maine. It is hoped that a long-term monitoring program can be established to collect information critical to the assessment and management of this important fisheries resource in the state of Maine.

Discussion

There was a question regarding the size of vessels involved with the fishery and how much they land per trip. G. Nutting indicated that they land approximately 210 tote boxes of sea cucumber per trip with about 145 lbs/tote.

Emerging Fisheries and Resource Assessment for Sea Cucumber (*Cucumaria frondosa*) off Newfoundland
Scott Grant, Don Stansbury, Elaine Hynick, and Paul Winger

Presentation Highlights

In the Newfoundland region, the orange-footed sea cucumber (*Cucumaria frondosa*) resource is currently at the commercial and stock assessment stage in which the emphasis is on determining whether the resource can sustain a commercially viable fishery and to collect scientific information on which to build data bases for stock assessment purposes. Various attempts were made to investigate the fishery potential for *C. frondosa* in the Newfoundland region in the early 1990s. Interest increased in 2001-2002, with dive landings of 113 t in coastal waters of Northwest Atlantic Fisheries Organization (NAFO) Divisions 3KL, and modified green sea urchin drag landings of 36 t on the St. Pierre Bank (NAFO Division 3Ps). In 2003, dive landings had decreased to 70 t, while drag landings increased to 441 t during the first year of a 5-year (2003-2008) limited entry fishery (8 fishing enterprises) on the St. Pierre Bank. An exploratory drag harvest was also initiated in the Strait of Belle Isle region (NAFO Division 3K) in 2003-2004. By 2004, the modified green sea urchin drag was adopted as the standard harvest method for the region. The annual allocation (round weight) in the limited entry fishery on the St. Pierre Bank (all 8 enterprises combined) increased from 454 t in 2003 to 613 t in 2007. The annual fishery is preceded by a research survey which is conducted by Industry and monitored by at-sea fisheries observers. For the research survey, the area of interest was divided into 32 10' × 10' (latitude × longitude) blocks which are further subdivided into 100 1' × 1' survey grids. Ten grids are randomly sampled annually from each block using a standardized tow length of 0.5 nm. The first survey to successfully follow this design was conducted in 2004 and produced a biomass estimate of 320000 t. In 2005, a low research survey biomass estimate of 106000 t was attributed to problems with the fishing gear, which resulted in the development of a reference manual outlining drag construction (Barrett et al. 2007). Biomass estimates for the remaining years ranged from 251000 t in 2006 to 362000 t in 2007. Two centres of *C. frondosa* distribution were found to occur on the St. Pierre Bank: one in the northwestern region and a second in the southeastern region of the bank. In these centres of distribution, catches have exceeded 400 kg in a standardized tow. Variability in annual commercial landings, which ranged from a low of 187 t in 2006 to a high of 503 t in 2007, is attributed to a combination of

varying levels of harvester participation and processor/harvester negotiations. In each year, the majority of the commercial landings are taken from the centre of distribution on the northwestern region of the bank due, in part, to proximity of this concentration to home ports. Incidental bycatch in the fishery is low (0.42% of sea cucumber landings), with over 71% being represented by echinoderms (seastars and sea urchins). Echinoderms also dominate the bycatch in the research survey. In 2007, identification of seastars to genera during the research survey revealed an overlapping distribution of a known predator of *C. frondosa* (*Solaster* spp.) within the centres of distribution.

A towed camera sled was used on the St. Pierre Bank to ground truth bottom classification data and provide density estimates by habitat type. *C. frondosa* distribution was patchy on all 4 bottom types identified. Highest *C. frondosa* densities (0.7-[illegible]2 individuals/m^2) were found on gravel-cobble followed by shell (0.2-0.7 individuals/m^2), sand (0.1-0.7 individuals/m^2), and rock (0.1-0.4 individuals/m^2). Identification of high densities of *C. frondosa* on sand bottom suggests bottom topography may also be an important factor contributing to observed habitat associations. It is conceivable that high energy storm events dislodge *C. frondosa* from preferred cobble-shell-boulder substrate and subsequently deposit them into low lying areas of finer sediments (e.g., sand), which may hinder the function of the water vascular system and ultimately their ability to move and feed.

A size index (SI = contracted length × contracted width × 0.1) was found to provide the best predictor of contracted (a.k.a., round) and eviscerated (gutted) wet body weight of *C. frondosa*. Low correlations (i.e., r^2=0.534-0.776) in the SI-eviscerated body weight relationships are attributed to high variability in body wall thickness at size within a population. A 4-6 mm difference in body wall thickness at a given size was not uncommon on St. Pierre Bank and may be related to habitat (i.e., sediment type/current strength). A comparison of the body wall thickness between *C. frondosa* from the St. Pierre Bank and coastal waters in the Strait of Belle Isle revealed a significantly higher body wall thickness in the Straits population. It is conceivable that high energy coastal areas lead to increased body wall thickness. Further, high within population variability in body wall thickness in both populations leads to implications of high within population variability in linear growth (i.e., SI). Body wall thickness increased and water content decreased throughout the summer months, which is indicative of a loss of energy reserves over winter during low food availability. Analysis of repeated within and between day measurements of contracted body length, contracted body width, and SI of individual *C. frondosa* indicated that these linear measurements can vary considerably throughout the day, and differed significantly from day to day in 2 of the 5 individuals examined. It is recommended that future studies only consider analyzing animals that exhibit a natural posture with podia extended and that teasing to contract, external measurements, and, where feasible, body weight be carried out, while *C. frondosa* are submerged in seawater. Body cavity water content (including the respiratory and water vascular systems) was found to differ significantly both spatially and temporally on the St. Pierre Bank, with *C. frondosa* exhibiting a gradual increase in water content (45.7-73.3%) throughout the summer months. Thus, research survey biomass estimates will vary monthly as will estimates of biomass landed during commercial fishing.

There was no evidence of external sexual dimorphism represented by the number of projections on the genital papilla during an examination of 250 *C. frondosa* from St. Pierre Bank. Males were found to possess from 1 to 21 projections, while females possessed 1 to 8 projections and the number of projections was independent of body size. On average, sex ratios were 1:1 in the St. Pierre Bank population. Spatial and temporal analysis of dry gonad weight-eviscerated body weight relationships, percent sperm activation, egg diameter distributions, and percentage of gonadal tubules swollen and level of swelling led to the conclusion that the St. Pierre Bank

population is comprised of several subpopulations that are spawning at different times so as to produce a protracted 2-3 month spawning season (April-June) over the entire bank. On the St. Pierre Bank, gametogenesis of males and females begins during the summer when food availability is high. Sexually mature *C. frondosa* from both the St. Pierre Bank and Strait of Belle Isle populations exhibited swelling of up to 100% of the gonadal tubules and percentage of swollen tubules was positively correlated with body size in a pre-spawning (early February) sample from St. Pierre Bank. Dry gonad weight-eviscerated body weight relationships indicate the reproductive potential of *C. frondosa* increases with an increase in body weight. Maturity ogives were established for a sample of *C. frondosa* collected in early February and indicated that males achieved sexual maturity at a slightly smaller body size than females. Contracted body length at first, 50%, and 100% sexual maturity in males was 5.2 cm, 8.7 cm, and 11.3 cm, while that of females was 7.0 cm, 9.3 cm, and 11.5 cm. Size index (no units) at first, 50%, and 100% sexual maturity in males was 2.2, 4.3, and 7.3, while that of females was 3.4, 4.8, and 7.2. Eviscerated wet body weight at first, 50%, and 100% sexual maturity in males was 24.8 g, 42.8 g, and 54.9 g, while that of females was 25.9 g, 51.0 g, and 59.4 g.

Discussion

A participant asked how biomass estimates were obtained from the survey data – in particular, how gear efficiency was assessed. D. Stansbury indicated that no attempt was made to quantify gear efficiency, but, rather, it was assumed that all sea cucumber on the tow path were captured and retained by the survey gear. Given that the gear is unlikely to remove all individuals in its path, reported biomass estimates may be considered minimum values.

Fisheries and Resource Assessment for Sea Cucumber in the Maritimes
Chris Jones, Valerie Bradshaw, Mike Campbell, Sherrylynn Rowe, Mark Lundy, Jim Simon, Nancy Shackell, Scott Coffen-Smout, and Tracy Horsman

Presentation Highlights

The Maritimes Regional presentation was comprised of four parts representing the perspectives of DFO Fisheries and Aquaculture Management Branch, Policy and Economics Branch, Science Branch, and Oceans and Habitat Branch.

Representing Fisheries and Aquaculture Management Branch, C. Jones presented a summary of management measures presently employed in sea cucumber fisheries in the Maritimes Region. Management measures include: at-sea observers (primarily in the form of Industry technicians, although there are occasional trips involving DFO certified at-sea observers to ground truth this information), 100% VMS (vessel monitoring system), total allowable catch levels (TACs) for each fishing zone, time limits (i.e., season and/or number of fishing days), 100% hail-out and hail-in, completion of standard monitoring documents and scientific logbooks during all trips, and dockside monitoring of catch ranging 20-100% depending on the area.

M. Campbell presented a brief economic overview of sea cucumber fisheries from both Canadian and Maritimes Region perspectives on behalf of Policy and Economics Branch. Canadian landings of sea cucumber increased to approximately 3400 t by 2006, down slightly from the 2005 total. For Atlantic Canada, the 2006 landings total was approximately 2500 t. While Atlantic Canadian landings represented approximately 72% of Canadian landings, they represented only 39% of total landed value due to the higher average price of the British Columbia product. In the Maritimes Region, landings reached 1910 t in 2006 and decreased to 1810 t in 2007. Sea cucumber total landed value was estimated at $715000 for 2007. Average prices to fish harvesters have increased to approximately $0.40/kg in recent years.

On behalf of Science Branch, S. Rowe presented an overview of sea cucumber fisheries and resource assessment in the Maritimes Region. Interest in harvesting sea cucumber (*Cucumaria frondosa*) in the Maritimes began in 1989. During 1990, an experimental project was undertaken to assess the feasibility of a sea cucumber fishery in St. Mary's Bay, Nova Scotia, but development of the fishery stalled due to lack of market potential as this species is thin-walled relative to other sea cucumber species fished internationally (Bradshaw et al. 1991). One experimental fishing licence was issued in 1996, although, again, the small catches of small thin-walled animals were not marketable (DFO 1996). In 1999, there was renewed interest in harvesting sea cucumber and 6 experimental/exploratory licences exist in the Scotia-Fundy area at present covering portions of both the inshore and offshore, as well as the eastern and western Scotian Shelf. The sea cucumber fishery is an emerging fishery in the Maritimes Region and like many emerging fisheries, there is little biological information to assess fishery sustainability. Small scale surveys have been conducted in some areas both before and after sea cucumber fishing activity. However, changes in factors such as survey area, survey design, vessel, and gear have made it difficult to compare survey catch rates over time. In addition to survey information, assessment of sea cucumber fishing activities currently includes an examination of landings, catch rates, size frequency data, and bycatch (DFO 2005, 2006a, 2006b). Landings in the Maritimes Region increased to a peak of approximately 1900 t in 2006, the year in which catch limits were implemented, and remained similar in 2007. Landings have been derived primarily from an inshore area of southwestern New Brunswick, although since 2006, an area in offshore NAFO Division 4W has also become an important source of sea cucumber landings. Trends in catch rates have been consistent with those that might be expected for an emerging fishery. Sea cucumber size composition is monitored in the fishery through daily sampling of the catch. Variables measured have included: contracted length, contracted wet weight, circumference, body wall thickness, and meat weight. Standard measuring procedures have been employed, but because sea cucumbers are comprised of 80-90% water and are able to swell and contract, there has been considerable variability in the data and investigation of improved size measurement techniques is warranted. Bycatch varied among fishing areas. Within the southwestern New Brunswick sea cucumber fishery, sea urchin was the most significant bycatch species by weight and represented approximately 3% of the sea cucumber catch. Key information gaps pertaining to the assessment of ecosystem impacts associated with sea cucumber fisheries in the Maritimes Region include reliable metrics of sea cucumber abundance (e.g., biomass estimates), life history data required to determine sea cucumber productivity (e.g., age/size at maturity, growth, fecundity), and an understanding of the impacts of sea cucumber fishing gear on the benthic habitat.

The last part of the Maritimes Regional presentation focused on spatial harvest planning for new and emerging fisheries and was presented by N. Shackell on behalf of T. Horsman and S. Coffen-Smout of Oceans and Habitat Branch. One of DFO's ecological conservation objectives is to protect habitat, and this can be applied to new and emerging fisheries. Marine reserves have been repeatedly recommended for sustaining fisheries, especially for sedentary species, and have worked in many areas. A suite of experts has recommended that the trial of marine reserves for sedentary species would indeed be worthwhile (Hilborn et al. 2004). This is particularly true for species that broadcast their gametes into the water column and require a minimum density of individuals to ensure fertilization success. Reserves, situated in high-density areas, can maintain a natural age structure and natural densities, both of which contribute to greater reproductive success and reduced vulnerability to the environment. As well, reserves can serve as sustainable sources of recruitment to marginal areas and provide important research control areas. Given the potential, it is reasonable to propose that a significant portion of high density habitat be protected in every new fishery, for example, sea cucumber.

Discussion

A participant asked whether at-sea observers identified all bycatch to species and Rowe indicated that it was variable. For example, there were records of thorny skate and winter skate, as well as unidentified skate species.

The Sea Cucumber Fishery in the Maritimes – An Industry Perspective
Elmina Richardson and Roger Foulem

Presentation Highlights

E. Richardson's presentation was based on her 12 years of experience in the sea cucumber industry. As 1 of only 2 licence holders in New Brunswick (both currently classified as 'Stage II – Exploratory'), Richardson brought to the table her knowledge of sea cucumber in general – its habitats and habits; how to harvest it; how to process it; and, how to ship it. She shared with workshop participants a professionally-shot video showing all processes relative to the sea cucumber harvest. In her presentation, she advocated upgrading the licences in both New Brunswick and Nova Scotia from 'exploratory' to 'commercial'. This would, she noted, afford the opportunity for expansion of the fishery and would enhance its reliability as a viable economic generator in coastal villages and towns. She encouraged the formation of a committee to engage in the planning process for the sea cucumber fishery and provide direction. As well, she advocated that a sea cucumber fisher from each of New Brunswick and Nova Scotia be included on such a committee.

Discussion

A participant noted that during her presentation, Richardson had expressed interest in having a well managed fishery and questioned what she thought this might involve. Richardson indicated that in her view, a well managed fishery would be sustainable in the long-term and would involve addressing some of the questions being raised during the workshop.

The Sea Cucumber Fishery in the Maritimes – An Industry Perspective
Jules LeBlanc

Presentation Highlights

On behalf of the Nova Scotia Sea Cucumber Joint Project Agreement (JPA) holders, J. LeBlanc spoke on the subject of standardizing the three stages of fishery development for an under-utilized species with regards to sea cucumber surveying and commercial harvesting. Topics reviewed included type of gear, Stage I-III methods and implementation, conservation, and limited entry licence status.

The main goal of sea cucumber harvesters and processors is to find abundant levels of stocks of sea cucumber which can sustain and maintain a commercial fishery for as long as economic conditions permit.

Discussion

The Chair indicated that he appreciated the plea for consistency related to this fishery expressed by both Richardson and LeBlanc and explained that a draft protocol for new fisheries science and management that has been recently developed in Maritimes Region (described in

presentation to follow) might help achieve consistency by laying out a clear plan with associated outcomes.

Fishery Sustainability and Ecosystem Considerations
Tana Worcester

Presentation Highlights

Sustainability (including environmental, social, and economic sustainability), which was mentioned several times during this workshop by Industry participants, means being able to meet the demands of the present without compromising the ability of future generations to meet their own needs. DFO's ecosystem approach to oceans management (EAM) has focused on environmental sustainability; however, it is important that EAM be implemented as efficiently as possible to ensure best use of limited resources.

EAM attempts to manage maritime activities to control human impacts on the marine ecosystem and enable us to respond to ecosystem influences on these activities. To ensure efficiency and coherence, EAM cannot be applied in an *ad hoc* manner, but must be conducted in a structured way. Firstly, we must manage impacts of human activities on *all* ecosystem components, not just on the harvested resources. Secondly, we need to be able to integrate cumulative effects across *all* human activities including fisheries, aquaculture, shipping, and industrial development. Finally, we need to be able to respond to changing environmental conditions such as effects of climate change. Within DFO, EAM is being implemented through a structured planning process including articulation of overarching objectives, development of more specific strategies that can be used to achieve these objectives, and identification of tactics/tools for implementation.

An ecosystem approach to fisheries management (EAFM) attempts to expand good fisheries management practice to address emerging conservation concerns and ecosystem objectives (e.g., productivity, biodiversity, and habitat). Traditionally, fisheries have been managed to maintain productivity of the harvested resource, focusing largely on controlling exploitation and defining management units that reflected stock structure. Under EAFM, this scope is broadened to include consideration of the role of the harvested species in the food web, the potential for incidental bycatch of other species, and the potential for other impacts to the environment/habitat. Recognizing that each fishery is unique and will have different ecosystem interactions, efforts can be made to prioritize the key interactions of each fishery to focus management and research strategies and make efficient use of often limited resources. Within the context of the sea cucumber fishery, it will be important to identify key risks and investigate the list of potential strategies to determine which ones are most likely to aid in achieving agreed upon management and conservation objectives.

Discussion

A participant asked how DFO interprets the ecosystem objective to limit trophic level removals with respect to trophic demands of higher levels. T. Worcester explained that this acknowledges the importance of links within marine food webs and intends to ensure that linkages are maintained despite fishing pressure – the idea is to ensure that fishing does not remove so much of a resource that its predators suffer demographic consequences. Worcester highlighted that this is not just a product of DFO Maritimes, but reflects national and international efforts that have been more than 10 years in the making.

Science and Management Strategies for Emerging Fisheries
Ross Claytor

Presentation Highlights

For this presentation, new fisheries were defined as:

1) "Fisheries involving new species and/or stocks that are not utilized or not fully utilized, and not currently covered by a management plan."
2) Fisheries that extend into previously unfished areas or unassessed areas may be considered as new fisheries..

New fisheries are characterized by having sparse information for decisions. A draft protocol for new fisheries science and management has been developed by a joint effort of DFO Oceans and Habitat, Fisheries and Aquaculture Management, and Science branches. It includes a new emphasis on ecosystem effects, indicates where documentation and review are required, and defines the broad strategies associated with each stage.

The draft protocol is outlined below:

1) Stage I: Screening (1-3 months), fishery potential, and red flags (≤2 seasons).
   a) Goal: Determine if economic catch rates are possible and to identify ecological impacts.
   b) How:
      i) On-board monitoring of catch and effort by position, bycatch, and gear description.
      ii) Experimental licences, no retention.
      iii) Phase should be short.
   c) Basis for decision: Catch rates or levels indicate that money can be made, no ecosystem red flags, information documented and reviewed.
2) Stage II: Evaluate move to a commercial fishery (multi-year).
   a) Goal: Determine if a long-term sustainable fishery strategy is possible.
   b) How:
      i) Biology, geographic distribution, and gear impacts.
      ii) Conduct mitigation experiments if necessary.
      iii) Explore management strategies.
      iv) Define well-managed stock.
   c) Basis for decision:
      i) Well managed stock with objectives can be defined.
      ii) Framework assessment undertaken prior to Stage III commencing.
3) Stage III: Full fishery (continuing).
   a) Goal: Implement chosen regulations consistent with long-term sustainable management strategy and objectives.
   b) How:
      i) Usual stock assessment and management protocols.
      ii) Increase information base from previous phases.
      iii) Plan and fine tune to changing stock and fishing effort.
   c) Basis for decision:
      i) Assessments with frequency outlined in framework.

It was emphasized that the protocol is a living process and is undergoing development. The protocol requires that interaction with Industry and DFO Fisheries and Aquaculture Management, Science, and Oceans and Habitat branches be increased. The major issues to be addressed are:

1) Improving evaluation of ecosystem effects,
2) Evolution of clarification of the differences between Stage I and II,
3) Building the framework – Stage II,
4) Cost, and
5) Use of fish.

Discussion

Following the presentation, Fuller noted that the northwest Atlantic is an ecosystem in which top predators have been severely depleted and we are now fishing further down the food web. In this regard, she questioned whether there should be a decision at some point that certain species would not be harvested. Jones replied that DFO Fisheries and Aquaculture Management would make such decisions and relies on meetings such as this one to hear from all stakeholders. Fuller continued by asking why we would apply an ecosystem approach to individual fisheries and not look at the big picture (e.g., determine that some minimal level of the food chain should remain intact). Worcester indicated that the Policy on New Fisheries for Forage Species may provide guidance on this issue, as well as ecosystem modeling by identifying critical linkages. Shackell indicated that highly abundant species such as sea cucumber probably play large roles in the ecosystem and efforts should be directed towards understanding and maintaining these roles (e.g., determining predator-prey relationships).

SCIENCE AND MANAGEMENT STRATEGIES

There was considerable discussion regarding management and assessment measures to address concerns regarding fishery sustainability and ecosystem impacts, as well as research and monitoring that would be required to support them. Sea cucumber science and monitoring pertaining to ecosystem objectives and strategies is summarized in Appendix 4.

It was noted that biomass estimates are currently lacking from most areas and this issue could best be addressed by implementing a standardized survey. A standardized survey would provide information about distribution, size/sex composition, and relative abundance. By determining efficiency and selectivity of the survey gear, biomass estimates could be calculated. Use of a liner in the survey gear would facilitate capture of small animals and development of a recruitment index. To avoid issues regarding gear saturation, the drag and tow duration may need to be modified for the survey relative to typical fishing activities. A survey would also provide an opportunity to obtain samples to assess life history variation including size at maturity. Histology may be required to assess maturity, although this could be accomplished in some instances (particularly just prior to the spawning period) by examination of gross morphology of the gonad. Prior to undertaking a standardized survey, size measurement protocols would need to be developed. Immersed weight and dry weight are considered standard metrics of sea cucumber size and are highly correlated. Unfortunately, neither of these metrics of size is appropriate for processing large numbers of individuals under field conditions. A project should be undertaken to assess whether other length or weight measurements that are better suited to fishery monitoring applications might be correlated with immersed weight and/or dry weight. Split weight (weight of the animal with an incision in the body wall to release excess water) has proven to be a useful metric of individual size for fishery applications

involving *P. californicus* in British Columbia and should be explored for *C. frondosa*. It will be important to ensure that techniques used to estimate biomass from the survey are comparable to landed weights as determined at dockside (based on round weight at present).

Given the relatively low mobility of sea cucumbers, it was suggested that depletion experiments may be informative with respect to assessing the relationship between effort and fishing mortality. Abundance estimates derived from a depletion study could also be compared to survey abundance estimates for the same area. In British Columbia, depletion studies were used to examine the merits of a rotational harvest strategy (e.g., how many years would it take populations to rebound if fished, frequency of rotation). Areas were depleted of sea cucumbers and then re-examined. Follow-up surveys suggested that the areas did not contain closed populations – within two years, sea cucumbers had moved in from other areas and were more abundant than prior to the depletion event. That being said, the duration of the depletion event was short relative to the rate of movement and, thus, the assumption of having a closed population was not violated for the purposes of assessing biomass and gear efficiency. A challenge associated with depletion experiments is selection of appropriate study areas so that it is possible to extrapolate to larger spatial scales. For example, sea cucumber abundance and gear performance may vary in relation to substrate type. In addition, sea cucumbers in some areas may exhibit higher rates of movement than in other areas.

In the absence of a method to age sea cucumbers, it is challenging to assess productivity and predict sustainable rates of exploitation. As a result, it was suggested that there may be merit in experimentally fishing areas at different levels of intensity (based on survey biomass estimates) and monitoring population impacts to determine what a sustainable harvest rate might be. This approach has been implemented for *P. californicus* in British Columbia and is proving useful. In this instance, 25% of the known sea cucumber distribution was open to fishing, 25% was reserved for research purposes (such as the experimental fishing project described), and 50% was closed. The rationale for this approach was to protect a large segment of the population until sufficient data could be obtained to inform management on appropriate harvest strategies/levels. It is anticipated that the sea cucumber fishery in British Columbia may ultimately move towards a rotational harvest. It was noted that a similar spatial management approach would likely prove useful in Atlantic Canada to avoid serial depletion of areas and large-scale reductions in sea cucumber density to levels whereby reproductive processes might be compromised (high densities are believed to be necessary to synchronize gonadal development and spawning).

Considering that the fishery for *C. frondosa* is prosecuted at present using mobile bottom-contacting gear, a number of concerns were expressed regarding potential habitat impacts and bycatch. As a result, there was some discussion regarding the feasibility of switching to a dive fishery, particularly in inshore areas. Participants indicated that while a dive fishery might be possible in some areas, strong tides would severely limit diving in locations such as The Passages in southwestern New Brunswick where much fishing takes place. In addition, it was noted that a dive fishery for *C. frondosa* might not be economically viable at present given the low value of the product (although product value may increase as the fishery and associated markets develop). Nonetheless, it may be possible to use existing information such as data from DFO ecosystem surveys and habitat mapping activities to focus sea cucumber harvesting in areas, whereby bycatch and habitat impacts are minimized.

RESEARCH PROGRAM NEEDS AND NEXT STEPS

In reviewing science and monitoring requirements pertaining to ecosystem objectives and strategies, five issues were deemed to be of particular importance:

1) Keep fishing mortality moderate.
   There are no mortality estimates at present and no definition of moderate fishing mortality. The sea cucumber fishery is a developing fishery with limits on factors such as number of licences and area fished. Standardized surveys should be undertaken to assess distribution, size/sex composition, and relative abundance. Efficiency and selectivity of the survey gear should be determined in order to calculate biomass. Catch and effort data should be assessed to monitor fishery impacts, depletion and/or tagging experiments undertaken, and growth rates and maturity ogives defined. Logbooks, DMP (dockside monitoring program) of landings, and at-sea observers were identified as other key monitoring tools. Bycatch of sea cucumber in other fisheries may be significant, and this source of mortality should also be considered.

2) Permit sufficient spawning biomass to evade exploitation.
   Market size is likely greater than size at maturity, but local sampling is required to verify. Size measurement and maturity staging protocols need to be developed so that size/age at maturity and growth rates can be defined, as well as catch composition and appropriate gear configuration for desired selection be determined. Monitoring should include documentation of catch composition by size and sex through use of at-sea observers and port sampling technicians. Minimum capture sizes need to be established. High densities of sea cucumber may be critical to enable chemical communication among individuals necessary to synchronize maturation and spawning. Required densities are unknown and research is needed to determine the relationship between sea cucumber density and fertilization success. Standardized surveys should be implemented to map sea cucumber distribution so that areas may be set aside to maintain appropriate densities for spawning and to protect aggregations of juveniles.

3) Distribute population component mortality as a percentage of component biomass.
   Population structure is unknown. Adults are believed to exhibit low rates of movement. A prolonged planktonic egg/larval stage suggests there might be high potential for gene flow, although oceanographic features could increase deposition in some areas and/or promote local retention. Distribution and abundance of adults and planktonic eggs/larvae should be assessed through standardized surveys. Associations between sea cucumber abundance and various habitat/oceanographic characteristics (e.g., depth, temperature, and bottom type) should be explored. Population structure may also be elucidated through basic biological and oceanographic sampling across areas, genetics, and tagging.

4) Limit incidental bycatch or mortality.
   Bycatch is potentially a concern. Identification of bycatch to the species level can be problematic for many invertebrates. Bycatch is typically reported by weight at present with a minimum of 1 kg recorded for any species encountered – counts of individuals would also be beneficial for some species, but they are not always recorded. An unknown level of sea cucumber discarding occurs at sea. Survival of discards has not been established. Guide rules need to be developed and should be based on the premise of minimizing bycatch, including sea cucumber discards. Bycatch should be quantified and mitigation strategies reviewed as necessary. Monitoring of bycatch should be accomplished through logbooks and deployment of at-sea observers. Bycatch species should be recorded by weight and

number of individuals as appropriate. Identification aids for key species (e.g., seastars) should be developed to assist observers.

5) Limit the percentage area disturbed of habitat/biotope/seascape types.
The sea cucumber fishery is prosecuted using mobile bottom-contacting gear for which habitat impacts have not been assessed. Habitat classification maps should be developed for areas where they do not currently exist. Other activities ongoing in the local area should be documented to assess relative impacts of the sea cucumber fishery. Experiments should be conducted to quantify both short- and long-term impacts of drags on different habitats or bottom types. Monitoring should include VMS and reporting of fishing location in logbooks on a tow by tow basis. It was noted that there would likely be a need to balance minimizing area disturbed against minimizing fishing pressure in any one location.

Time did not permit detailed discussion of timelines and costs associated with these research and monitoring priorities, nor how they might be accomplished. Further discussion of these issues will be required in the future.

CONCLUDING REMARKS

The Chair confirmed that the draft proceedings would be circulated for review and comment before being finalized. He then thanked all the participants for a stimulating discussion and adjourned the meeting.

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Appendix 1. Terms of Reference

Workshop on Canadian Science and Management Strategies for Sea Cucumber (*Cucumaria frondosa*)

17–18 June 2008
Auditorium, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

Terms of Reference

Context

Interest in harvesting sea cucumber (*Cucumaria frondosa*) in the Maritimes began in 1989 but the fishery was slow to develop mainly due to lack of market potential as this species is thin-walled relative to other sea cucumber species fished internationally. One experimental fishing licence was issued in 1996 although the small catches of small thin-walled animals were not marketable. In 1999, there was renewed interest in harvesting sea cucumber and 6 experimental/exploratory licences exist in the Scotia-Fundy area at present. Experimental sea cucumber fishing activities have also been ongoing in the Gulf of Maine since 1988 and off Newfoundland since the 1990s.

While the sea cucumber fishery is an emerging fishery in Atlantic Canada, Fisheries and Oceans Canada has recognized that a requirement exists to develop a comprehensive fisheries management plan governing activities of current and future licence holders. Although there is little biological information available from the Maritimes, other regions (e.g., Newfoundland) and countries (e.g., USA) have undertaken scientific studies on this and related species (e.g., Pacific sea cucumber (*Parastichopus californicus*)). In this regard, there is a need to develop an understanding of the information that exists to assist management, the approaches that could be used for management, and future information needs.

Objectives

- To develop a conceptual model, including uncertainties, on the biology of the sea cucumber resource.
- To discuss fishery sustainability and ecosystem considerations.
- To discuss management approaches to the sea cucumber fishery and related decision support tools.
- To discuss information requirements for future management of the resource.
- To outline a research program in support of the management decision making.

Outputs

CSAS Proceedings
CSAS Research Document (if appropriate)

Participation

DFO Science representatives
Industry members knowledgeable about the fishery
Fisheries managers
Members of the university community and other non-governmental organizations

Topics for Discussion

Potential topics for discussion are outlined below by elements of the decision process. This is not an inclusive list but rather is to indicate the breadth of the expected discussion.

Population Model

The population model summarizes our understanding of the processes governing the sea cucumber population from the biology through to the fishery.

Regarding the population, what is known about movement and population structure? Other key issues concern production and mortality processes. What is to be learned from its growth processes? Through analogies with related species and stocks, what can be said about recruitment production? What do we know and need to know about the role of sea cucumber in the ecosystem?

Regarding the fishery, there is a need to understand its impacts on the ecosystem. What do we know and what research is required?

In summary, what is our understanding of the biological processes governing sea cucumber and what research is required?

Assessment Model

The assessment model includes both observational activities, such as the industry logbooks, and procedures used to supply indicators for management decisions.

There are a number of possible assessment models to pursue, all of which have their strengths and weaknesses – from Surplus Production, through Delay-Difference to Age/Size Models. Information requirements and thus costs vary dramatically by model. It is likely that size-based methods will be needed. What are the program requirements of the most appropriate and cost-effective assessment approach?

What other information would be beneficial for management?

Decision Support

Management decisions are linked to particular levels or directions of the indicators termed 'reference points' and 'reference directions' respectively. These decision points depend upon the objectives that one hopes to achieve. Can we state these, at least in a preliminary way? What research do we need to undertake to define appropriate reference points?

Management Measures

Management needs to regulate the fishery. How can this best be achieved – quotas, effort controls, size limits, area restrictions, etc.? What are the related monitoring requirements?

Appendix 2. List of Participants

Workshop on Canadian Science and Management Strategies for Sea Cucumber (*Cucumaria frondosa*)

17–18 June 2008
Auditorium, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

Participants List

Participant	Affiliation
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Appendix 3. Agenda

Workshop on Canadian Science and Management Strategies for Sea Cucumber (*Cucumaria frondosa*)

17–18 June 2008
Auditorium, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

Agenda

17 June 2008 – Tuesday

09:00 – 09:15	Introduction (Claytor)
09:15 – 09:45	Overview of Sea Cucumber Ecology (So/Mercier)
09:45 – 10:15	Sea Cucumber Ecology Discussion – *conceptual model of sea cucumber population*
10:15 – 10:30	Break
10:30 – 11:00	Global Overview of Sea Cucumber Fisheries and Resource Assessment (Mercier)
11:00 – 11:30	Lessons Learned from Targeted Fisheries and Ecosystem Impacts (Fuller)
11:30 – 12:00	Fisheries and Resource Assessment for Sea Cucumber off British Columbia (Duprey)
12:00 – 13:00	Lunch
13:00 – 13:30	Fisheries and Resource Assessment for Sea Cucumber in the US Portion of the Gulf of Maine (Nutting/Chen)
13:30 – 14:00	Fisheries and Resource Assessment for Sea Cucumber off Newfoundland (Grant)
14:00 – 15:00	Fisheries and Resource Assessment for Sea Cucumber in the Maritimes (Jones/Bradshaw/Campbell/Rowe/Lundy/Simon/Shackell/Coffen-Smout/Horsman)
15:00 – 15:15	Break
15:15 – 15:45	The Sea Cucumber Fishery in the Maritimes – An Industry Perspective (Richardson/Foulem)
15:45 – 16:15	The Sea Cucumber Fishery in the Maritimes – An Industry Perspective (LeBlanc)
16:15 – 18:00	Sea Cucumber Fisheries and Management Discussion – *current management measures and data inputs from fishery*

18 June 2008 – Wednesday

09:00 – 09:30	Fishery Sustainability and Ecosystem Considerations (Worcester)
09:30 – 10:30	Fishery Sustainability and Ecosystem Considerations Discussion – *given our current understanding of the biological processes governing sea cucumber and of sea cucumber fisheries, what are our concerns surrounding sea cucumber sustainability and broader ecosystem impacts of the fishery?*
10:30 – 10:45	Break
10:45 – 11:15	Science and Management Strategies for Emerging Fisheries (Claytor)
11:15 – 12:00	Science and Management Strategies for Emerging Fisheries Discussion
12:00 – 13:00	Lunch
13:00 – 15:00	Science and Management Strategies for Sea Cucumber Discussion – *what are the best management and assessment measures to address concerns regarding fishery sustainability and ecosystem impacts?* – *what research and monitoring would be required to support these management and assessment strategies?*
15:00 – 15:15	Break
15:15 – 17:00	Research Program Needs and Next Steps Discussion – *what are the priorities for research and monitoring?* – *what timelines and costs would be associated with these research and monitoring priorities?* – *how might research and monitoring be accomplished?*
17:00	Adjournment

Appendix 4. Science and Monitoring Pertaining to Ecosystem Objectives and Strategies

Objective – Sub-objective	Operational or emerging strategy with performance indicator	Guide rule incorporating management measure, performance indicator or proxy, reference point	Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice	Associated or proposed monitoring	Rationale
Productivity – Primary productivity	Limit alteration (excluding catch removals) of essential nutrient concentrations affecting primary production	No guide rule at present.			Not applicable. Sea cucumber operations do not notably alter nutrient concentrations.
Productivity – Community productivity (trophic structure)	Limit trophic level removals with respect to trophic demands of higher levels	Ensure removals do not exceed reference point (to be developed).	Examine existing diet information (e.g., DFO Maritimes Stomach Data Base) and inclusion of sea cucumber in Ecopath models.		Inclusion of sea cucumber in Ecopath models may help elucidate role in ecosystem.
Productivity – Community productivity (trophic structure)	Limit total removals within system production capacity	Ensure removals do not exceed reference point (to be developed).			
Productivity – Population productivity	Keep fishing mortality moderate	Developing fishery. Limit number of licences, area fished. Set TAC so risk of fishing mortality exceeding reference point (to be developed) is low.	Assess CPUE trends, determine gear efficiency and selectivity, undertake depletion or tagging experiment, define growth rates and size/age at maturity.	Survey, logbooks, DMP of landings, at-sea observers. Record location by tow, size composition of catch.	No mortality estimates at present, no definition of moderate fishing mortality. Need to incorporate mortality from other fisheries.

Objective – Sub-objective	Operational or emerging strategy with performance indicator	Guide rule incorporating management measure, performance indicator or proxy, reference point	Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice	Associated or proposed monitoring	Rationale
Productivity – Population productivity	Permit sufficient spawning biomass to evade exploitation	Selectivity > size at maturity (to be determined). Set closed areas to maintain high densities for spawning.	Determine relationship between sea cucumber density and fertilization success. Develop population model.	Survey, logbooks, at-sea observers, port sampling. Record location by tow, size and sex composition, reproductive state of catch. VMS.	High densities may be critical to enable chemical communication among individuals necessary to synchronize maturation and spawning. Density required unknown. Chemical communication among individuals in shallow and deep areas also important as photoperiod appears to be the cue.
Productivity – Population productivity	Promote positive biomass change when biomass is low	No guide rule at present. Set TAC so risk of not achieving positive biomass change is low.	Determine efficiency and selectivity of survey gear to convert CPUE to biomass.	Survey, logbooks, DMP of landings.	No biomass estimates at present.
Productivity – Population productivity	Manage % size/age/sex of capture	Needs to be developed. Set minimum capture size. Set closed areas to protect high densities of juveniles.	Develop size measurement and maturity staging protocols, define size/age at maturity and growth rates, determine catch composition and appropriate gear configuration for desired selection, map distribution of juveniles.	Survey, at-sea observers, port sampling. Record catch composition. VMS.	Market size is likely greater than size at maturity but local sampling required to verify.

Objective – Sub-objective	Operational or emerging strategy with performance indicator	Guide rule incorporating management measure, performance indicator or proxy, reference point	Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice	Associated or proposed monitoring	Rationale
Productivity – Population productivity	Prevent disturbing activity in spawning areas/seasons	No guide rule at present. Set closed areas/seasons to protect spawning.	Assess life history including location and timing of spawning.	Conduct basic biological sampling.	Location of spawning unknown although no evidence to suggest migration. Spawning time likely April-June but local sampling required to verify.
Productivity – Population productivity	Manage discarded catch for all commercial species	Needs to be developed. Minimize bycatch including sea cucumber discards.	Quantify bycatch of commercial species, review mitigation strategies as necessary, assess survival of discards, determine best practices for release.	Logbooks, at-sea observers. Record bycatch including sea cucumber discards.	Bycatch of other commercial species potentially a concern. Unknown level of sea cucumber discarding at sea. Survival of discards unknown.
Biodiversity – Biotope/ seascape (community diversity)	Limit % area disturbed of biotope/seascape types	No guide rule at present. Prohibit fishing in closed areas, develop rule if closed areas inadequate to protect diversity.	Develop habitat classification maps, determine other activities ongoing in area to assess relative impacts, conduct experiment to quantify short- and long-term impacts of drags on different habitats.	Logbooks. Record location by tow. VMS. In-situ observation (i.e., ROV).	Fishery uses mobile bottom-contacting gear. Habitat impacts have not been assessed. Need to balance minimizing area disturbed against minimizing fishing pressure in any one location.

Objective – Sub-objective	Operational or emerging strategy with performance indicator	Guide rule incorporating management measure, performance indicator or proxy, reference point	Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice	Associated or proposed monitoring	Rationale
Biodiversity – Biotope/ seascape (community diversity)	Limit trophic level removals to keep trophic levels in proportion in order to conserve trophic structure	Ensure removals do not exceed reference point (to be developed).	Determine efficiency and selectivity of survey gear to estimate absolute biomass and abundance of sea cucumber, assess trophic structure of ecosystem and changes over time, quantify impacts of fishing on trophic structure, use modeling to assess sensitivity of ecosystem to changes in trophic structure.	RV surveys, industry surveys, CPR, AZMP.	Sea cucumber may remove large amounts of plankton from water column and contribute significantly to plankton community during spawning.
Biodiversity – Species diversity	Limit incidental bycatch or mortality for all non-commercial species	Needs to be developed. Minimize bycatch.	Quantify bycatch, review mitigation strategies as necessary. Develop identification aids for key species (e.g., seastars) to assist observers.	Logbooks, at-sea observers. Record bycatch species by weight and number of individuals as appropriate.	Bycatch potentially a concern. Identification to species level can be problematic for many invertebrates. Bycatch typically reported by weight with minimum of 1 kg recorded for any species encountered - counts of individuals also beneficial for some species but not always recorded.
Biodiversity – Species diversity	Minimize change in distribution of invasive species	No guide rule at present.	Quantify bycatch of invasive species. Review mitigation strategies as necessary.	Logbooks, at-sea observers. Record bycatch of invasive species.	

Objective – Sub-objective	Operational or emerging strategy with performance indicator	Guide rule incorporating management measure, performance indicator or proxy, reference point	Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice	Associated or proposed monitoring	Rationale
Biodiversity – Population diversity	Distribute population component mortality as % of component biomass	No guide rule at present.	Document distribution and abundance of adults and planktonic eggs/larvae, examine associations with habitat/oceanographic features, determine population structure.	Surveys, basic biological and oceanographic sampling, genetics, tagging.	Population structure unknown. Adults believed to exhibit low rates of movement. Prolonged planktonic egg/larval stage suggests high potential for gene flow although oceanographic features could increase deposition in some areas and/or promote local retention.
Habitat – Bottom	Limit % area disturbed of habitat types	No guide rule at present.	Develop habitat classification maps, determine other activities ongoing in area to assess relative impacts, conduct experiment to quantify short- and long-term impacts of drags on different bottom types.	Logbooks. Record location by tow. VMS. In-situ observation (i.e., ROV).	Fishery uses mobile bottom-contacting gear. Habitat impacts have not been assessed. Need to balance minimizing area disturbed against minimizing fishing pressure in any one location.
Habitat – Water column	Limit amounts of contaminants, toxins, and waste introduced in habitat	No guide rule at present.			Not applicable.
Habitat	Minimize amount of lost gear	No guide rule at present.			Not applicable. Low incidence of gear loss.
Habitat	Control noise or light level/frequency	No guide rule at present.			Not applicable.